ENGINEERING CASE LIBRARY

J.L. ADAMS CORPORATION[1]

Areas for Improvements in Functional Artificial Arms

The Engineering Case Program at Stanford recently reviewed a memorandum dated September 30, 1964, from the Committee on Prosthetics Research and Development of the National Academy of Sciences, The memorandum, part of which is shown in Appendix I, is a compilation of suggestions for student design projects in the fields of artificial limbs, leg braces, and control devices for handicapped individuals. This list of projects was shown to Mr. T. R. Parke, Vice President of a company that makes artificial arms.[2] The casewriters hoped that he could provide background information for a case study based upon some of the suggested problems. He replied that his company did not have funds to attack any of the problems listed. "Though our company makes the key components in over 90% of all upper extremity prostheses worn in the United States, we have not been able to afford an engineer from the date of our incorporation in 1943 until a year ago. Our company has developed very useful and reliable products mainly by design collaboration between top management and our machinists."

"Government contracts for work on the more exotic problems in prosthetics usually go to organizations whose main line of activity is something else, such as education, general research, or even defense production. We would like to get ideas for some of our future products from these government sponsored prosthetic investigations, but unfortunately many of the engineers on these projects don't really understand the needs of amputees. We are forced to concentrate on these needs, because our whole business is manufacturing prostheses for these people to wear."

"Although our products have been developed, tested, and proved in wide usage over more than a decade, we feel that our engineering efforts should still be concentrated on improving them. The sort of question we would like to have answered, for instance, would be how can the design of our mechanical elbows be improved?"

[1] Real name withheld by request.

[2] The technical name for an artificial arm is an "upper extremity prosthesis".

Prepared in the Design Division, Department of Mechanical Engineering by David A. Horine under the direction of Karl H. Vesper. The assistance of the firm and the financial support of the National Science Foundation are gratefully acknowledged.

The Company and Its Products

The J. L. Adams Corporation manufactures the basic components for over 90% of the functional artificial arms used in the United States. It exports 25% of its products to about 30 other countries. The company has 25 employees, and the company engineer is also the company draftsman and model maker. Mr. Parke feels that there is not enough work to justify hiring a full time engineer.

The company usually does not deal directly with end users of its products. Most arms are sold through independently operated retail shops[1] which custom tailor the prostheses to individual amputees. Typically, a customer comes to the shop on the referral of his doctor. He is then interviewed and measured to determine the optimum shape and strength prosthesis for his particular range of applications. Then, an arm is built up from components supplied by Adams, such as elbows, cables, and wrist connections, and from plastic parts made at the fitting shop.

Because it does not usually deal directly with its customers, Adams has found that product defects often do not come to its attention when they occur. For example, the company recently received a letter from a customer informing them that the customer's wrist joint would often jam. The company engineer made some tests at the plant and found that the wrist units in stock also jammed. He then called some of the fitting shops and discovered that they had been modifying the elbows with the addition of a rubber washer and had not bothered to inform Adams of the trouble.

Almost all of the 1200 different items produced at Adams are hand made, because the company management feels that it cannot justify the cost of mass production tooling. "Most of the parts that we make are low production items," said Mr. Parke, "and therefore the only way that we could make mass production economical would be to produce the same design for a number of years. We are reluctant to freeze our designs for the time required to pay for the tooling."

The major production facilities at the plant are listed below:

4 turret lathes (max. collet 2-1/2" dia.)	1 22-ton punch press
4 horizontal lathes (9-16" swing)	1 small spot welder
2 vertical mills (18" bed travel)	1 small arc welder
2 horizontal mills (18" bed travel)	tumbling equipment
1 tool room type jig bore	8-drill drill press bank
plastic fabrication shop for resin and cloth laminates	5-spindle drill press

[1] These shops are known in the prosthetics industry as "fitting facilities".

Design at Adams

Occasionally, the company has hired an outside engineering firm to do design work, but most parts have been designed by the management and other employees. "We have a very ingenious machinist at Adams," said Mr. Parke. "Before we hired an engineer, I would go to him and verbally describe what I needed. He would 'hog' out a part that he thought would do the job, and we would test it out for a while. Then I would go back and tell the machinist what was wrong with the part. We would go through a series of these iterations until we were satisfied with our design."

"We are just beginning to make mechanical drawings of our mechanims," said Mr. Parke. "Our machinists have usually taken their dimensions from the parts that they are duplicating. This has been a satisfactory arrangement in most cases, but we did have a problem once. We found that some of our mechanical elbows were jamming. All of the parts inside looked as if they should have worked, so it took us quite a while to track down the source of trouble. We finally found that one of our machinists had incorrectly cut a sector gear by a few thousandths of an inch. We had to throw away all of the defective gears."

Mr. Turner, who has repaired elbow units at the company for fifteen years, told of another way that products are designed at Adams. "We are a small company and everyone knows everyone else. Therefore, it's easy for us to let the management know about anything that we think should be improved. If I find that some part keeps breaking on the arms that I repair, I will tell the foreman or the President or Vice President about it and suggest some ways the problem might be corrected." For a suggestion that is used, Mr. Parke said that Adams will reward an employee with as much as the resulting estimated saving for one year.

"We designed a small beryllium-copper spring a few years ago, and the first lot that we produced worked fine," recalled Mr. Turner. "However, the second lot of springs were brittle and broke after a few cycles of bending. We thought that improper heat treatment might have been the problem, so we had two different heat treating companies make some of the springs. These springs also failed after a few cycles. We never did find out what was wrong. Finally, we designed another spring with a new shape and made these from steel instead of beryllium-copper. We have had no trouble with the new spring."

Mr. Parke feels that an important asset to his company is the fact that he has worked in the field of prosthetics prior to coming to Adams, and the fact that he wears two artificial arms.

Upper Extremity Prosthetic Devices

A distinguishing feature of prostheses made from Adams components, according to the company, is that these units will permit an amputee to perform many manipulative tasks that a real arm can perform. Mr. Parke states that it is impossible to list the deficiencies of a prosthesis as compared to a real arm since these deficiencies vary for different amputees. Adeptness in using a prosthesis is affected by such factors as the amputee's age, training, strength, and mental attitude. Exhibit 1 shows some of the tasks that a prosthesis wearer can perform. Mr. Parke adds that there is one exception to his general statement. None of the existing upper extremity prostheses provides much tactile feedback. This is not considered a great problem by his company. However, it can cause difficulties when an amputee must hunt for a light switch in a dark room or attempt to locate change in his pants pocket.

Exhibit 2 shows a number of possible configurations for upper extremity prostheses. The hand[1] on most of these units is a pair of opposing metal tongs called a split hook. "There are some terminal devices on the market that resemble real hands," said Mr. Parke. "However, these devices do not perform nearly as well as split hooks. Furthermore, they can cause awkward situations when someone shakes hands with a person that wears one. These hands look very realistic; however, they are cold to touch, and this can come as a shock. The terminal devices that resemble hands are a lot more expensive, on the average, than split hooks; the most popular 'cosmetic hand' sells for about $135 while the average split hook sells for about $65." A number of split hooks are shown in Exhibit 3, and some of their applications are shown in Exhibit 4. One tong is connected to a steel cable which is attached by straps to the amputee's shoulder (Exhibit 5). The amputee may pull on the cable by moving his shoulder. The cable in turn pulls on one of the tongs causing it to pivot away from the other one. When the shoulder is relaxed, several rubber bands, connected between the two tongs, pull them together. Each rubber band provides one pound of "pinch," and five or six are usually used.

A threaded stud, protruding from one end of the split hook, fits into a socket on the wrist. Some of these wrist sockets are shown in Exhibit 6. The socket allows the amputee to rotate his split hook about the connecting stud by turning the hook with his other hand. He can also lock his hook in a fixed position if he desires with some units. Some wrists contain quick-change devices that allow the amputee to interchange terminal devices conveniently.

The wrist unit is laminated to a piece of plastic material corresponding to the forearm. The type of forearm and remaining parts in a prosthesis depends upon the length of the amputee's stump relative to the remaining joints in his arm. If the amputation is below the elbow, the plastic forearm is hinged to a plastic cuff that straps to the amputee's upper arm. If the amputee's forearm stump is long enough, it is fitted into a socket in the plastic forearm. The stump and plastic forearm then

[1] An artificial hand is known in the prosthetics industry as a "terminal device".

move together as a unit (2A). If the forearm is amputated close to the elbow joint, it is mounted in a socket that is hinged to both the plastic cuff and plastic forearm. The hinge is a "step-up type" that provides a mechanical advantage to multiply the force from the forearm stump to the plastic forearm (2B).

If an arm is amputated at or above the elbow, a mechanical elbow is used (2C,D,and E). An elbow unit permits the amputee to flex his forearm about an axis that approximates the axis of rotation in a human elbow. A mechanism contained in the mechanical elbow can be used to lock the forearm in several positions about this axis. The mechanism is actuated by another cable that connects to the amputee's shoulder. A pull on the cable will release the lock and allow the forearm to be rotated by the other arm to a new position. Another pull on the cable will lock the arm again. Some mechanical elbows allow the amputee to swivel his forearm about an axis running the length of his upper arm. The mechanical details of elbow locking mechanisms are described in Appendices C and E.

Plastic parts, such as the forearm and upper arm, are usually made in plaster molds which are in turn made from casts of the amputee's stump. The plastic material consists of approximately five laminations of woven tubular nylon cloth saturated with polyester resin. This makes a hollow shell about 3/8" thick (thickness ranges from 1/4" to 1/2"). Glass fiber and nylon are used together in places where extra strength is required. However, nylon alone is usally preferred since it is available in seamless shapes, it impregnates with resin better than does glass, and it does not fray. The last feature is particularly important since glass fibers can irritate the skin. Woven cotton is used instead of nylon for the outer lamination. Mr. Parke says that the weave of the cotton improves appearance.

Artificial Limb Design Parameters

Exhibit 7 is a form used by the fitting facilities for recording the data necessary to build a prosthesis. If the Adams Corporation is to build the arm, they will receive this form together with a tracing of the amputee's sound arm and a plaster cast of the stump. The information requested on the form indicates some of the design parameters that Adams considers. For example, knowing the amputee's race, pigments that approximate the amputee's skin color can be added to plastic parts.

Mr. Parke observed that it would be inefficient to have a bank clerk wearing an arm that has been designed for a lumber jack: "A lumber jack needs an arm of maximum strength, and this would be unnecessarily heavy for a man who lifts nothing more than a stack of dollar bills." Therefore, his company wants to know the amputee's occupation. Knowing this, appropriate materials and a hook designed for the amputee's occupation can be selected.

Mr. Parke was asked what he thought were some important parameters that an engineer should consider in prosthetics design. "A lot of engineers try to over-design. I have met engineers who can design artificial arms that are almost perfect from a functional standpoint, but they are so complicated that they would fill up an entire room. The size of such an

arm would be just one of its problems. Amputees have what we call a 'gadget tolerance'. That is, there is a limit to the number of clever devices that you can put in a prosthesis. If a guy has to wiggle his ears to move his hook, he will refuse to wear one."

"Reliability is a very important design consideration," Mr. Parke continued. "Imagine a situation like this: An amputee who needs his arm for his work is living a hundred miles from his prosthetics fitting facility, and a 50 cent spring breaks in his elbow joint. He is unable to use his arm, so he has to leave his job and get the arm repaired. This could take a number of weeks, since the fitting facilities normally do not carry spare parts."

"We tell amputees that they should treat their artificial arms as they would treat real ones. Unfortunately, we can't always count on their doing this. I heard of a mechanic, for example, who would stick a crow bar under a car to lift it up. After he had gotten it up, he would wedge his split hook in where the crow bar was and hold the car with his hook while he moved the crow bar to a new position. That guy would need a heavy duty steel split hook."

Mr. Turner has had an opportunity to see what happens to units after several years of use. "Once in a while, we get back an elbow that is bent or broken. I have tested these elbows myself, and I know that it takes a lot of force to break one. They still seem to do it. I got an elbow from Florida that had sand and salt water in it. This is one of the reasons that we make our metal parts of anodized aluminum and stainless steel. However, the anodizing can wear through after a while, and even sweat is corrosive enough to attack unprotected aluminum. Despite these problems with a few units, our arms usually can be worn for a number of years before they require maintenance. Most of the bearing surfaces, for example, use Oilite bushings and rarely need to be lubricated."

"The range in size of the people that we must fit has caused some design problems," said Mr. Parke. "We scale our parts to fit several size ranges, and this means that we need a lot of tooling for parts that would be made in small quantities even if there were only one standard size. Scaling causes some more problems. It can be difficult to build such things as springs in a size small enough for small children. Also, it is difficult to assemble child-size mechanisms."

Problems with Existing Prostheses

"Our products have a record of continuous satisfactory performance," said Mr. Parke, "but there are some areas where they could be improved."

"We need a better constant friction wrist connection. It is desirable to be able to rotate the hand to different positions about the longitudinal axis of the forearm. A welder might want to rotate his hand to one position for holding a welding rod and to another position for picking up a fork. The rotating connection should have sufficient friction so that it will stay in the position to which it is set, but it should not have so much friction that it becomes difficult to adjust. Our present connections tend to bind or loosen up and are continually

being readjusted. The cable that opens the split hook exerts a torque on the hook when it is pulled. Thus, if the wrist joint is loose, the hand will turn when you try to open it. The ideal joint should have some provision for setting the friction initially, so that it would be suitable for either a logger or a baby, and it should be capable of being repositioned about eighty times a day for the life of the arm. An arm can last as long as twenty years, but the average life is from three to five years." The mechanical details of an existing unit are described in Appendix B.

"Our elbow locking mechanisms could be improved also. One problem is that when an amputee wants to lock or unlock his elbow, he has to make an awkward 'monkey motion' with his shoulder; he moves his stump down and back while his shoulder moves forward. This is a difficult motion for amputees to learn. The best way of solving this problem would be to design a solenoid elbow lock that could be controlled by flexing a muscle against a sensitive electric switch. Two Federal Agencies are presently working on such an electric elbow, but they haven't come up with anything practical yet. One of their designs does not permit the arm to swing free when the elbow is unlocked. With this design, an amputee would look stiff if he walked with his arms at his sides." (Existing elbows are described in Appendices C and E.)

"A second problem is that, due to a lack of available space, some of our elbow locking mechanisms are not very strong. We usually mount the locking mechanisms inside the elbow, and in that location we have sufficient room to make the unit sturdy enough for most applications. Unfortunately, some amputees have had amputations at the elbow joint[1], and their stumps fill up the space where we would normally locate the locking mechanism. In such a situation, the most efficient thing to do would be to amputate the arm back to the place that would permit us to use the internal elbow unit. However, it's hard to make a person go back to the hospital after he has once had an amputation. Also, insurance companies pay for amputations by the inch, so they are reluctant to have any arm cut away for prosthetics fitting purposes. We are forced to design around this problem and mount a locking mechanism along the outside of the prosthesis (2D). We can't let the mechanism protrude very far from the sides of the elbow, since it would be cumbersome, so we must make it smaller than we would like. As a result, our externally mounted unit can only take half the torque (600 inch-pounds) of the internal unit. We have a real need for a stronger external unit." (The existing mechanism is described in Appendix E.)

"We have another problem that is caused by the lack of space in elbow disarticulation prostheses. There is insufficient room to mount a joint that will allow the forearm to turn about the longitudinal axis of the upper arm. The stump occupies the space where the joint, (usually referred to at Adams as a 'turntable') is usually located. In this situation, we must fix the angle of the arm, and there is no way of readjusting it."

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[1] An amputation at a joint is known as a "disarticulation".

"Appearance is a problem with our counterbalance unit, which is used to support the weight of the forearm (Appendix D). It protrudes from the side of the internal locking elbow mechanism and makes the elbow look awkward. I would like to mount it inside the elbow where it would not be visable, but there is not enough room in the present internal locking elbow to do this (Appendix C). Due to the appearance problem, we don't even make a counterbalance for elbow disarticulation prostheses (Appendix E). The external locking mechanism for these prostheses already protrudes too far from the side of the elbow, and we cannot tolerate any more appendages. Any spring-assist design should have an adjustable force so that it could counterbalance terminal devices of different weights. The maximum weight of a cosmetic hand is one pound, and the maximum weight of a hook is six ounces. The device must also support the weight of the forearm which, as a rule-of-thumb, is about one ounce per longitudinal inch."

Appendix A: List of Prosthetics Design Problems

(Excerpts from a brochure prepared by the Committee on Prosthetics Research and Development of the National Academy of Sciences National Research Council.)

INTRODUCTION

This brochure has been prepared by the Committee on Prosthetics Research and Development to serve as a guide to the Faculty of Engineering and Design Schools in developing problems of the handicapped for student design projects.

Listed herein are some typical design problems relating to Prosthetics and Orthotics together with a brief description. In addition, a few specific problems have been developed in more detail to illustrate how they might be used in student programs at both under-graduate and graduate levels.

It is hoped that student participation in this field will stimulate new concepts in the solution of the problems, provide the students with very real projects, and interest them in Rehabilitation as a career.

Further information may be obtained from:

Mr. A. Bennett Wilson, Jr.,
Technical Director,
Committee on Prosthetics Research and Development
2101 Constitution Avenue
Washington 25, D. C.

CONVERTING ELECTRICAL ENERGY TO PNEUMATIC ENERGY

A number of reasonably well-designed components now exist for use of external power in upper extremity prosthetic systems. Development work so far has yielded pneumatic motor mechanisms of high quality and reliability. However, employment of pneumatic systems requires rather bulky yet portable energy sources (small compressed CO^2 containers or "bottles") which are charged at some inconvenience to the wearer using large cylinders to be stored in his home. A.C. electrical sources are available in most home and offices; ideally electrical energy should thus be used to charge a portable pneumatic power source. There is a need for development of a simple portable system by which A.C. power can be used to charge a portable pneumatic power source.

References:

There has been some work done by Heather et al. in Delaware on a system of this sort, but there is very little in the form of reference material except materials which deal with pneumatic motor mechanisms already developed. Some pertinent information regarding end use in -- The Application of External Power in Prosthetics and Orthotics, National Academy of Sciences, National Research Council, Publication 874, 1961, Washington, D. C.

Appendix A (continued)

COMPRESSED GAS GENERATOR FOR POWERED PROSTHESES

Gas-operated, externally powered upper extremity prosthesis components require frequent refilling of gas containers at pressures of 1500 to 2000 psi. by means of special filling devices. Substantial improvement could be effected if the tanks could be filled by solid pellets, liquids or powdered chemicals at room temperature which would produce adequate volumes of gas inside the tank under the action of a catalytic additive. In effect, the user would simply bleed the depleted tank to atmospheric pressure, open it, deposit measured amounts of the appropriate materials, seal the tank and wait for the reaction to produce the gas. Ideally, the reaction should be controlled by a pressure threshold and limit.

Reference:

No specific reference available. Some pertinent information regarding end use in -- The Application of External Power in Prosthetics and Orthotics, National Academy of Science, National Research Council, Publication 874, 1961, Washington, D. C.

DESIGN OF AN EXTERNALLY POWERED ARM PROSTHESIS

A person has been involved in an acccident resulting in the amputation of one arm through the shoulder joint. This type of amputation, known as a shoulder disarticulation, is one of the most difficult to fit with a conventional "body powered" arm prosthesis. The lack of an upper arm stump as an active source of power for movement and control of the prosthesis requires that an external source of energy be provided. This source of energy must be small enough and lightweight enough to be carried by the amputee under his clothing. The arm should provide a replacement for those functions considered essential in activities of daily living. A considerable body of knowledge is available which will be helpful in establishing design criteria for such a device.

References:

1. Artificial Limbs, May 1955 Issue.
2. Artificial Limbs, Sept. 1955 Issue.
3. Human Limbs and Their Substitutes, Klopsteg, Wilson et al. An account of the research carried out under the Committee on Prosthetics Research and Development, National Academy of Sciences, through 1954.
4. Snelson and Marsh, "Design and Development of an Externally Powered Arm Prosthesis". An account of a similar development.
5. Paul and Mann, ASME Paper 62-Wa-121, "Evaluation of Energy and Power Requirements for Externally Powered Upper-Extremity Prosthetic and Orthotic Devices."
6. "The application of External Power in Prosthetics and Orthotics." Published 874, National Academy of Sciences, National Research Council.

Appendix A (continued)

7. University of California, Dept. of Mechanical Engineering, ME 124 - Design Project - Spring 1964.
8. Keller, A. D., C. L. Taylor, and V. Zahm, Studies to determine the functional requirements for hand and arm prosthesis, Department of Engineering, University of California, Los Angeles, 1947.

TERMINAL DEVICE (T. D.) SHAPES

Most T. D.'s are based on the split hook or two fingered hand principle. A study of T. D. shapes to provide optimum grasp for a maximum number of tasks is indicated. The results of this study would have application in remote manipulators as well as prosthetics.

References:

1. Northrop Aircraft, Final Report on Artificial Arm and Leg Research and Development, 1951 under National Research Council.
2. Orthopaedic Appliance Atlas Volume II, published by J. W. Edwards, Ann Arbor, Michigan.
3. Studies of the Upper-Extremity Amputee, Prosthetic Usefulness and Wearer Performance, by Hector W. Kay and Edward Peizer, Article in Artificial Limbs, Autumn 1958, National Research Council.
4. Keller, A. D., C. L. Taylor, and V. Zahm, Studies to determine the functional requirements for hand and arm prosthesis, Department of Engineering, University of California, Los Angeles, 1947.

OPTIMUM FRICTION AND RESILIENCE FOR ARTIFICIAL HANDS AND HOOKS

The abilities to grasp and release objects is particularly a function of the friction characteristics of the materials in contact and the resilience of the grasping surface. Although high friction is desired for holding - low friction has advantages in sliding hands in the pockets, etc. The optimum values for friction and resilience for various areas of the appliance should be determined.

References:

1. Report Second Workshop Panel on Upper-Extremity Components, Subcommittee on Design and Development, COMMITTEE ON PROSTHETICS RESEARCH AND DEVELOPMENT, National Research Council, Washington 25, D. C.
2. Studies of the Upper-Extremity Amputee, Prosthetic Usefulness and Wearer Performance, Hector W. Kay, Edward Peizer, in Artificial Limbs, Autumn 1958, National Academy of Sciences, National Research Council.

Appendix A (continued)

HAND AND HOOK: COMBINED MECHANISM FOR VOLUNTARY-OPENING AND VOLUNTARY-CLOSING

Several artificial hands and hooks have been designed using different types of internal mechanisms so that through voluntary cable motions amputees could either open or close the hand against a spring force used to return the hand to the original position. Hands or hooks have been made with either function available but not both. It would be desirable to design a hand or hook which with very simple modifications could be converted from one type of function to the other.

References:

1. A voluntary-opening and voluntary-closing hand or hook can be made available as well as drawings showing the mechanisms of both types.
2. Descriptions of artificial hands and hooks can be found in Orthopaedic Appliance Atlas, Volume II, published by J. W. Edwards, Ann Arbor, Michigan, 1960 Issue.

SOCKET VENTILATION BY NORMAL MOTION

Recent designs of sockets for the amputee's stump have employed very close fitting non-porous plastics. Some amputees have complained of perspiration accumulation and discomfort from lack of ventilation. Socket ventilation should enable the stump to "breathe" and to allow perspiration and water vapor to escape. A system design is needed particularly for the lower extremity prosthesis wherein certain functions such as the required resistances to foot flexion and extension or knee flexion and extension could be used to provide ventilation around the stump surface. Many above knee sockets use suction to keep the limb on. It is desirable that the ventilation system be applicable to suction sockets.

References:

There is little reference material available except that which discusses the desired functions of knee and foot-ankle mechanisms which might be used for ventilation sources. One approach to socket ventilation is described and has been developed by the Navy Prosthetic Research Laboratory, U.S. Naval Hospital, Oakland 14, California.

Appendix A (continued)

CENTER CONTROL TERMINAL DEVICE

Artificial hands or hooks are usually operated by a control cable connected to shoulder harness -- to improve appearance and to enhance efficiency at various positions of wrist rotation the appliances should be developed with a central or axially located control cable or rod.

References:

Northrop Aircraft Inc.,
Final Report on Artificial Arm and Leg Research and Development.
Second Workshop Panel on Upper-Extremity Components, Subcommittee on Design and Development, COMMITTEE ON PROSTHETICS RESEARCH AND DEVELOPMENT, National Research Council, Washington 25, D. C.

CO^2 PORTABLE BOTTLE RECHARGING SYSTEMS

Carbon Dioxide stored in small bottles is used as an energy source for activating artificial arms and upper extremity bracing. Refilling the bottles from a larger container is a hazardous task that is difficult to perform. There is a need for a home refilling method that is safe and can be operated easily by a handicapped or one-armed person.

References:

The Application of External Power in Prosthetics and Orthotics, National Academy os Sciences, National Research Council, Publication 874, 1961, Washington, D. C.

ELECTRICALLY OPERATED - PNEUMATIC VALVES

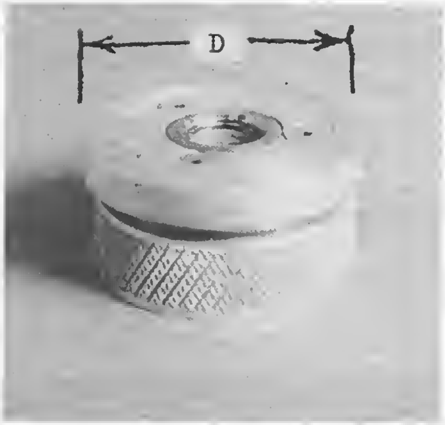
Many prosthetic and orthotic devices use CO^2 stored in small bottles and regulated to about 75 psi to operate pistons etc. to provide active function. Also under development are electronic signal and control systems (EMG for example), and it is desirable that these controls be applied to the pneumatic actuators. There exists a need for an electric-pneumatic valve whereby a variable electrical signal can be used to control a correspondingly variable gas flow. A 12 volt electrical system can be considered standard.

References:

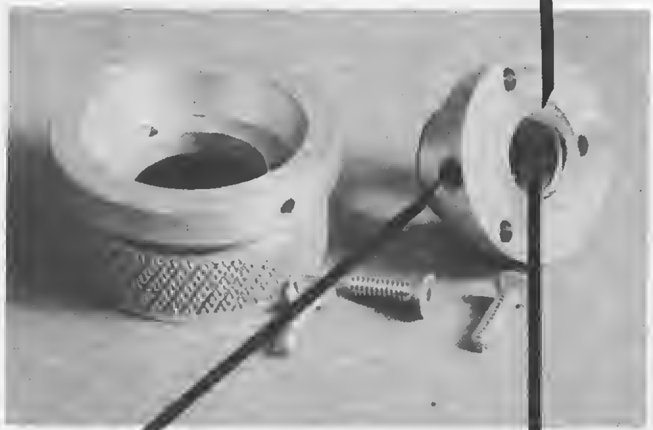
The Application of External Power in Prosthetics and Orthotics, National Academy of Sciences, National Research Council, *Publication 874, 1961, Washington D. C.*

Appendix B: Adams Friction Wrist

1



2



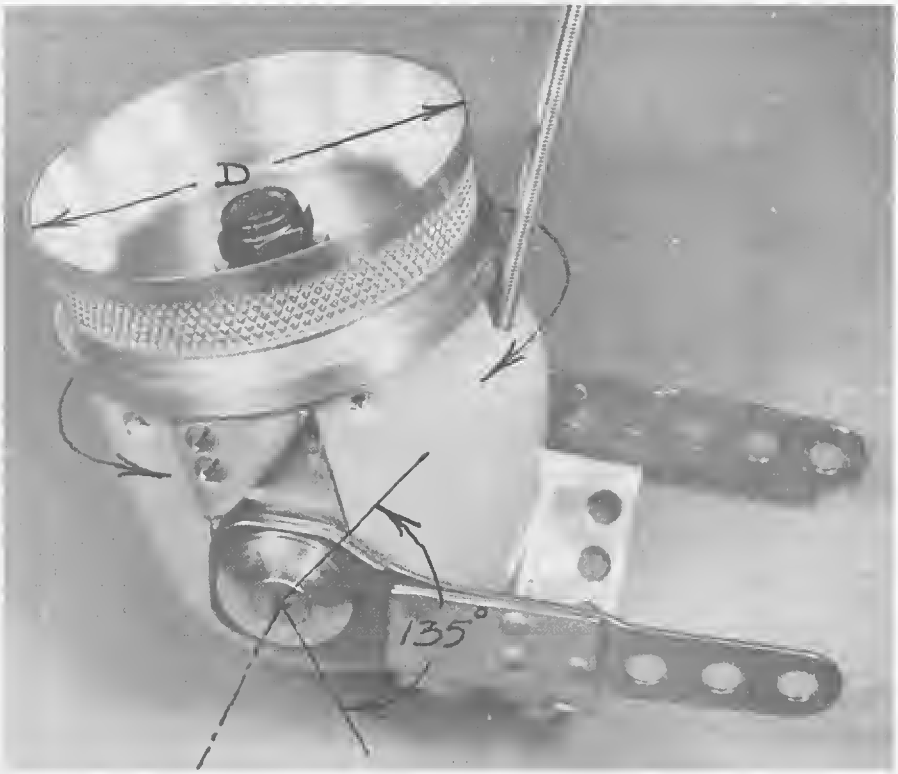
Picture 1 shows a typical mechanical wrist unit. This wrist holds a terminal device and allows it to rotate about the longitudinal axis of the forearm. Rotation is accomplished by manually screwing and unscrewing the terminal device.

The lower half of this unit is laminated to the plastic forearm. The upper half protrudes from the end of the forearm. Its top surface contains a threaded hole in which the bottom of the terminal device is screwed. The ends of the threaded section are made from stainless steel inserts, and the center section is a piece of Delrin plastic. Plastic is used to provide fairly constant friction when the terminal device is being turned. The steel inserts hold the plastic in place and prevent cross-threading of the plastic when a terminal device is being screwed in.

Picture 2 shows a partially disassembled wrist. The part on the right, which contains the threaded plastic insert, is removable so that it can be replaced if the plastic is damaged. A set screw, shown in this picture, pushes the threaded plastic section against the threaded part of the terminal device. It is used to adjust the amount of friction in the threaded joint.

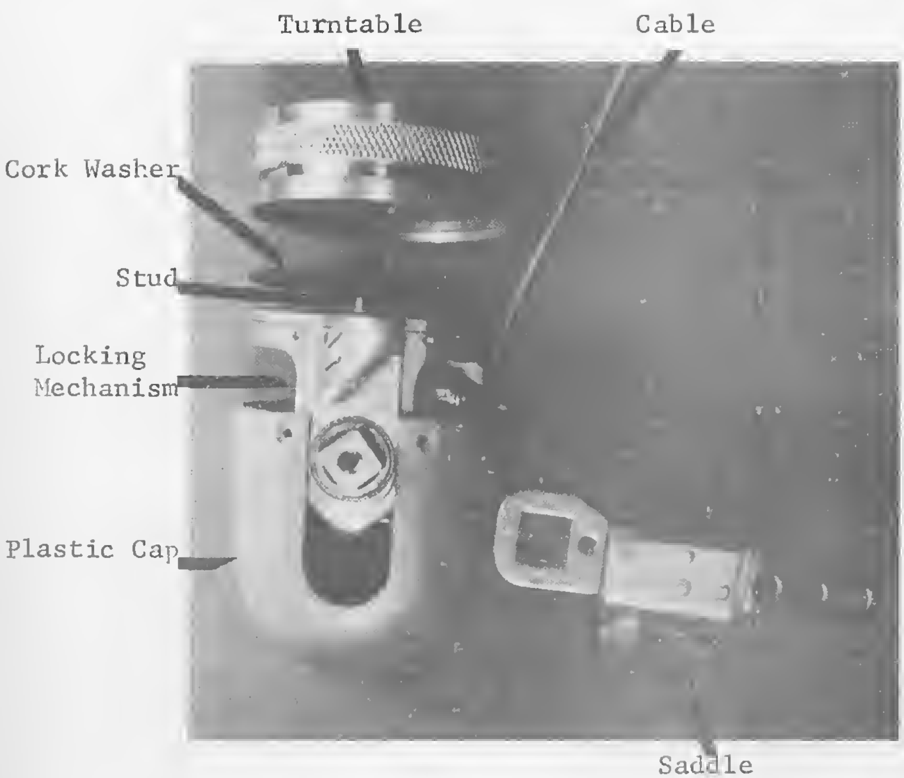
The wrist is available in four sizes: Adult (D = 2"), Medium (D = 1-5/8"), Medium Small (D = 1-3/8"), and Small (D = 1-1/4"). It retails for about $12.50.

Appendix C: Adams Internal Locking Elbow



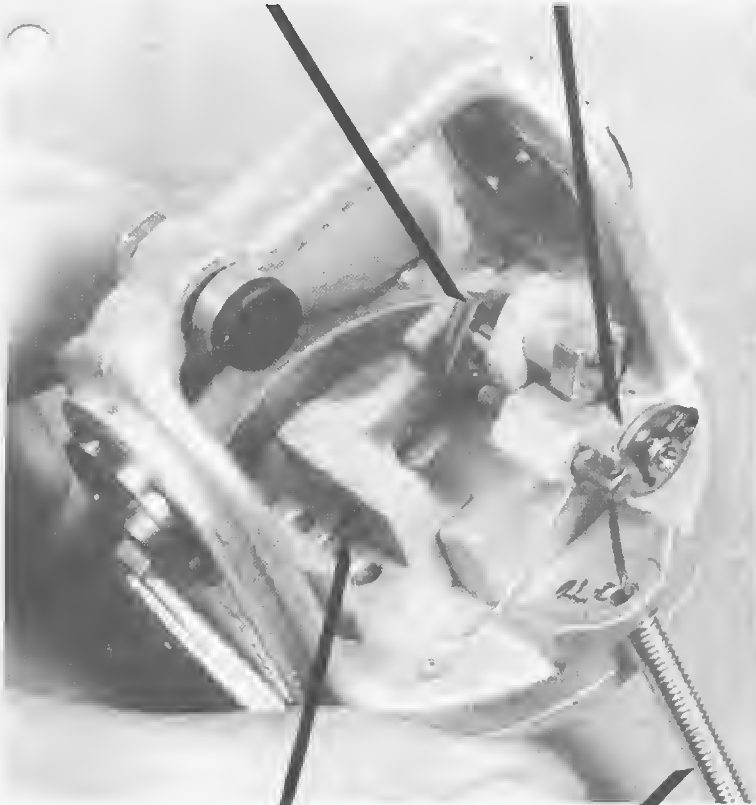
The picture shows a mechanical elbow used for above-elbow amputation prosthesis. With the elbow, an amputee can lock his forearm in 11 equally spaced positions through an angle of 135° about an axis that approximates the axis of rotation in the human elbow. It can support torques of about 1200 inch-pounds about this axis. The elbow also allows the amputee to swivel his forearm about the longitudinal axis of the upper arm. This unit is incorporated in the prostheses shown in Exhibit 2C and E.

The elbow is made in three sizes: Standard (D = 2-13/16"), Medium Small (D = 2-3/8"), and Child (D = 2"). About 1500 elbows are sold per year at an average retail price of $110.



A partially disassembled elbow is pictured. The turntable is laminated to the bottom of the plastic upper arm. It has knurling which provides a gripping surface for the plastic. The turntable serves as the stationary part of a joint that allows the forearm to turn about the longitudinal axis of the upper arm. The turntable and washer fit over the stud and are held to the top of the locking mechanism by a lock nut. The washer provides a friction bearing between the turntable and the top of the locking mechanism. Friction force is proportional to the tightness of the lock nut. After the arm is assembled, access to this lock nut is obtained through the top of the hollow upper arm.

The right half of the saddle is laminated to the plastic forearm. Holes in this portion of the saddle fill with plastic, thus locking the forearm to the saddle. The square holes in the left half of the saddle fit over the square ends of a shaft which connects to the locking mechanism.



1

2

The internal locking mechanism is shown in pictures 1 and 2 with a few parts removed.

The end of the cable is joined to the ratchet. The ratchet and the square cam are mounted on a common shaft. When the amputee pulls on the cable with his shoulder, the ratchet and the cam rotate 45°; when the amputee relaxes his shoulder, a spring inside the ratchet mechanism returns the cable to its initial position.

The locking bar is forced against the cam by a spring. As the cam turns, the bar moves up and down.

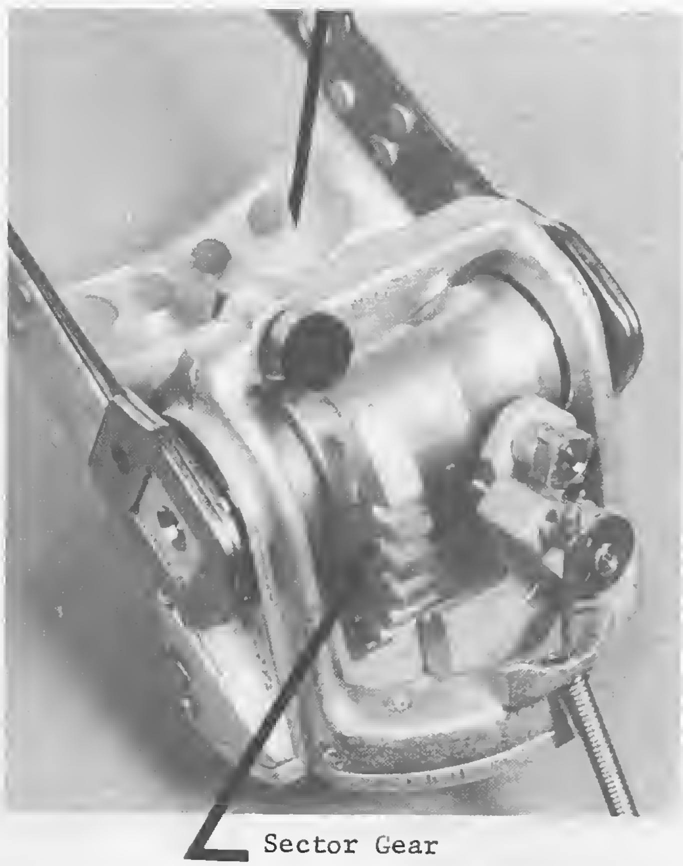
Picture 1 shows the bar in a position where it can lock into a sector gear, shown assembled to the unit in picture 3.

In picture 2, the bar is retracted, and the sector gear would be disengaged.

Picture 3 shows the assembled locking mechanism.

The sector gear is keyed to a shaft whose ends are screwed to the upper flanges of the saddle. Thus, the forearm is locked and unlocked by locking and unlocking the sector gear.

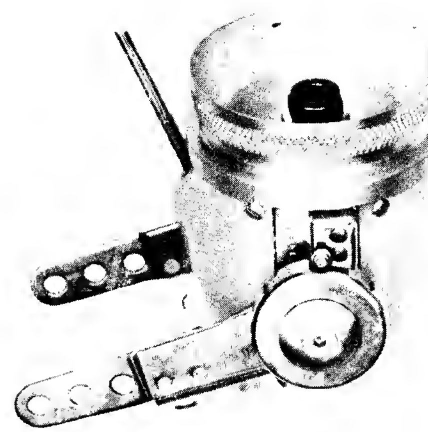
3



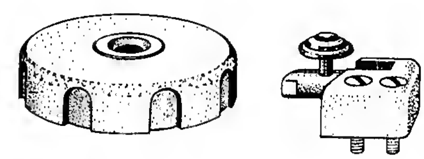
Appendix D: Forearm Counterbalance Unit

The forearm counterbalance ("lift assist") unit aids the amputee in positioning his forearm by counterbalancing the torque that the forearm exerts about the elbow joint. About 500 units are sold yearly as an accessory attached to the internal locking elbow. Retail price is about $25.

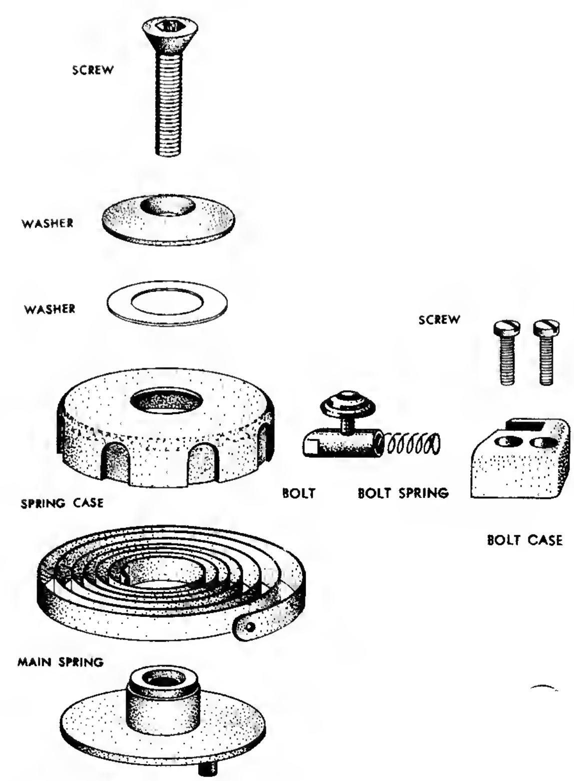
Spring counterbalance tension is set by manually rotating the spring case. The case is held in position by a sliding bolt. To release spring tension, the bolt is disengaged from the spring case by pulling on it.



LIFT ASSIST ELBOW

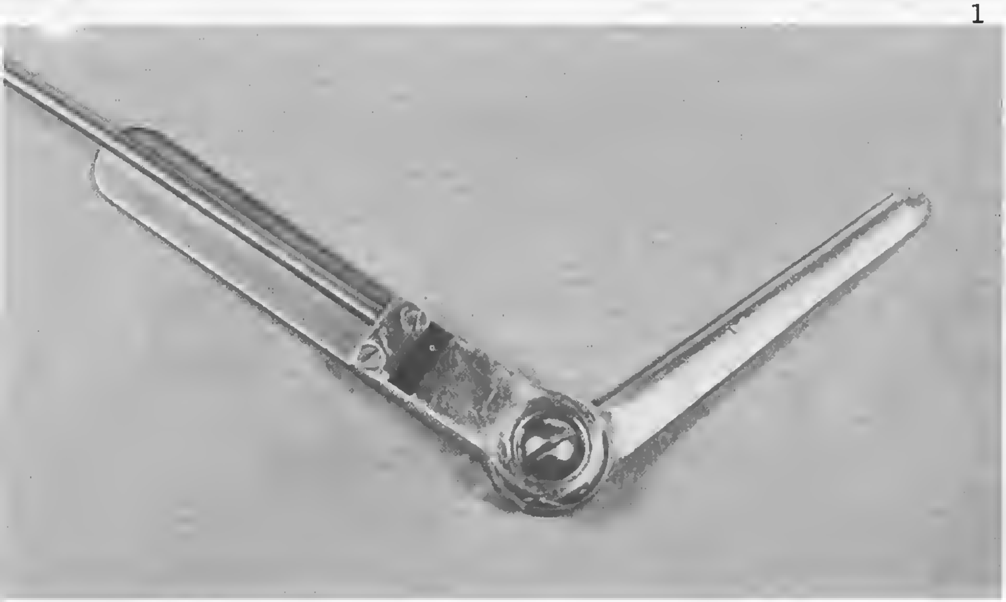


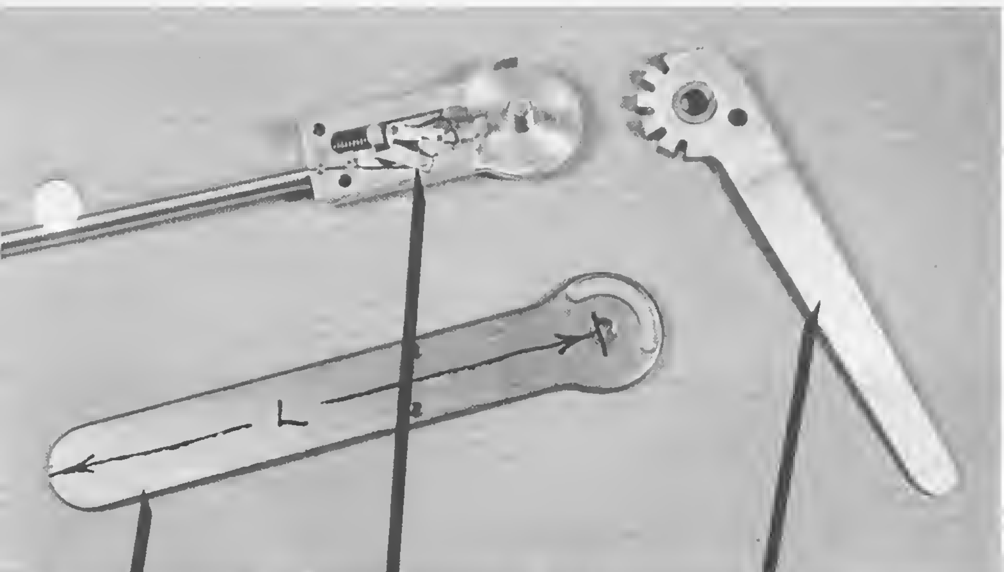
LIFT ASSIST UNIT



Appendix E: External Elbow Locking Unit

1





2

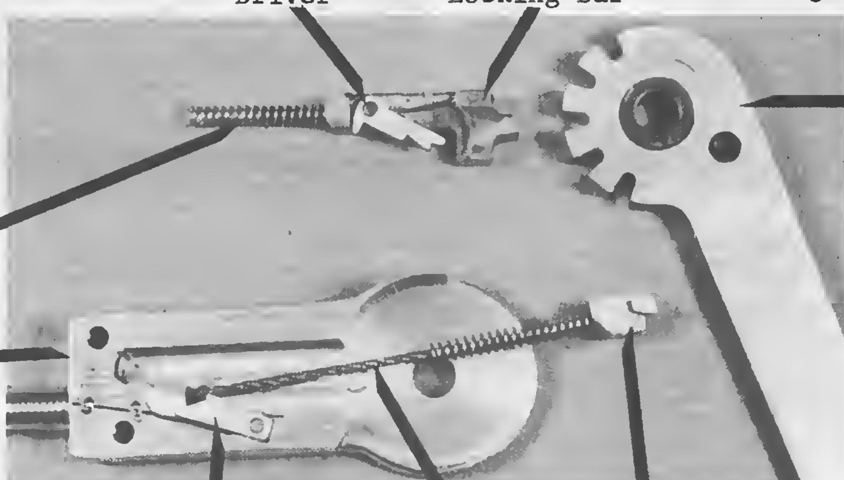
The external elbow locking unit is used on elbow disarticulation prostheses to allow the amputee to lock his forearm in several positions, (Child size: 5 positions; Medium size: 6 positions; Adult size: 7 positions), equally spaced through an angle of 145° about an axis that approximates the axis of rotation in the human elbow.

The forearm and upperarm flanges are laminated into the plastic upper arm and plastic forearm respectively. Before lamination, the fitting facilities drill holes in these flanges so that the plastic will lock to the metal.

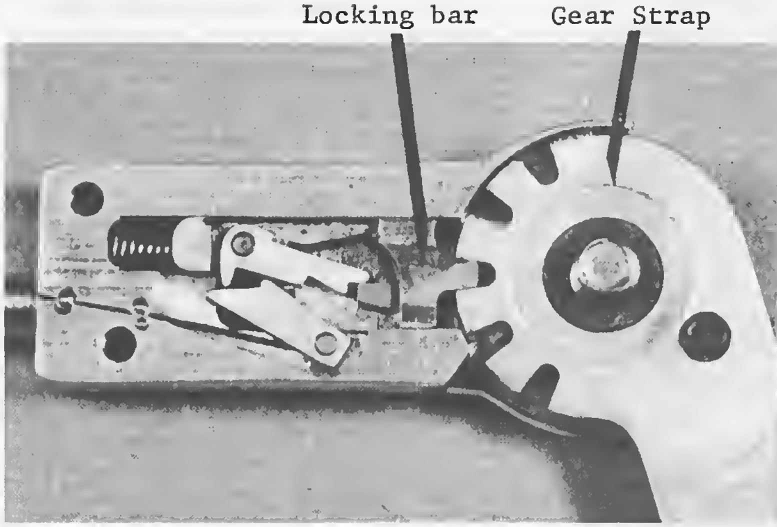
A partially disassembled unit is shown in picture 2, and a prosthesis using one of the units is shown in Exhibit 2D. Usually, one side of the elbow joint contains such a locking unit, and the other side contains a simple hinge. In cases where the amputee needs a heavy duty prosthesis, two of the external locking units are used. The elbow is made in three sizes: Standard (L = 6-1/2"), Medium (L = 5-1/2"), and Child (L = 4"). About 150 units are sold per year at a retail price of approximately $90.

Picture 3 shows the disassembled locking mechanism.

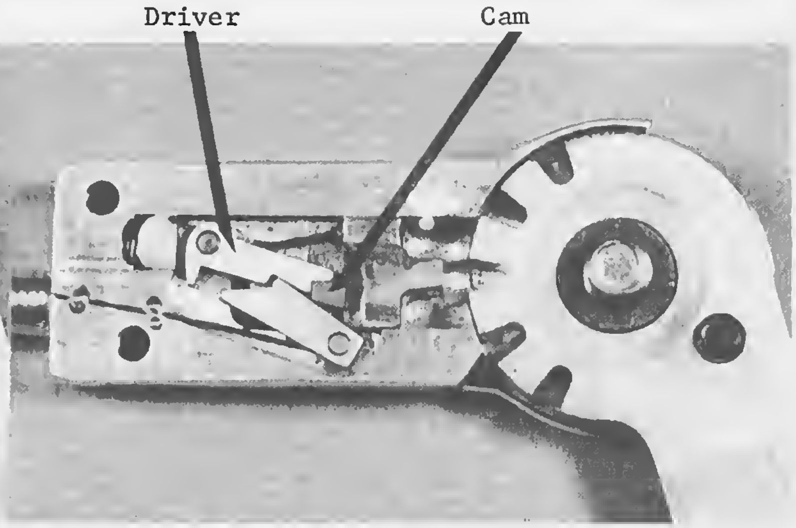
3



Appendix E: continued

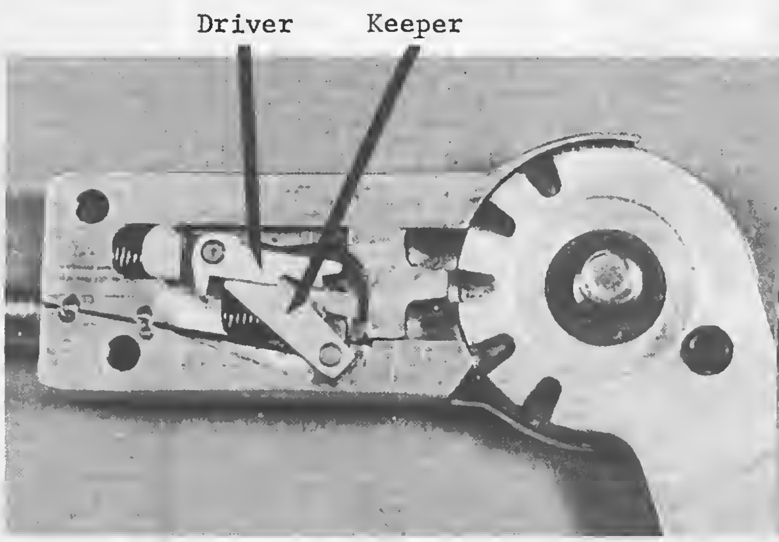


1

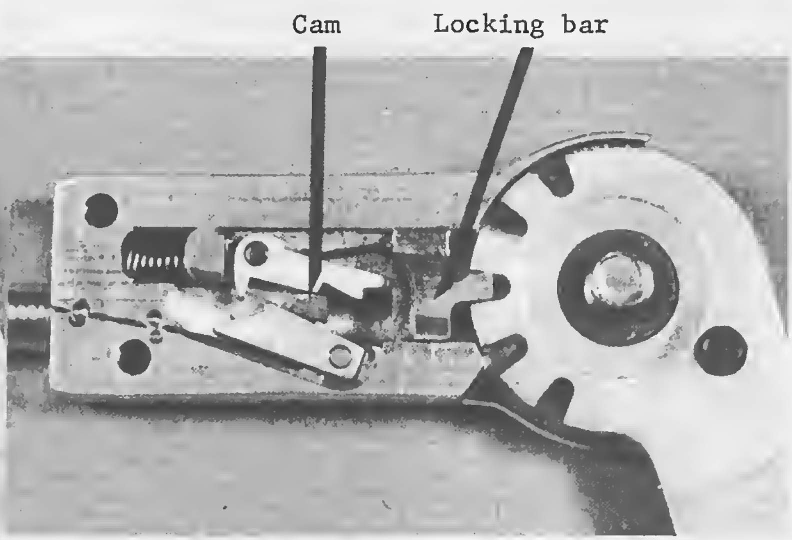


2

The operating sequence of the elbow locking mechanism is as follows. In picture 1, the locking bar is engaged with the gear strap and the elbow is locked. In picture 2, the cable has been pulled by the amputee, and the cam engages the driver, pushing the locking bar away from the gear strap.



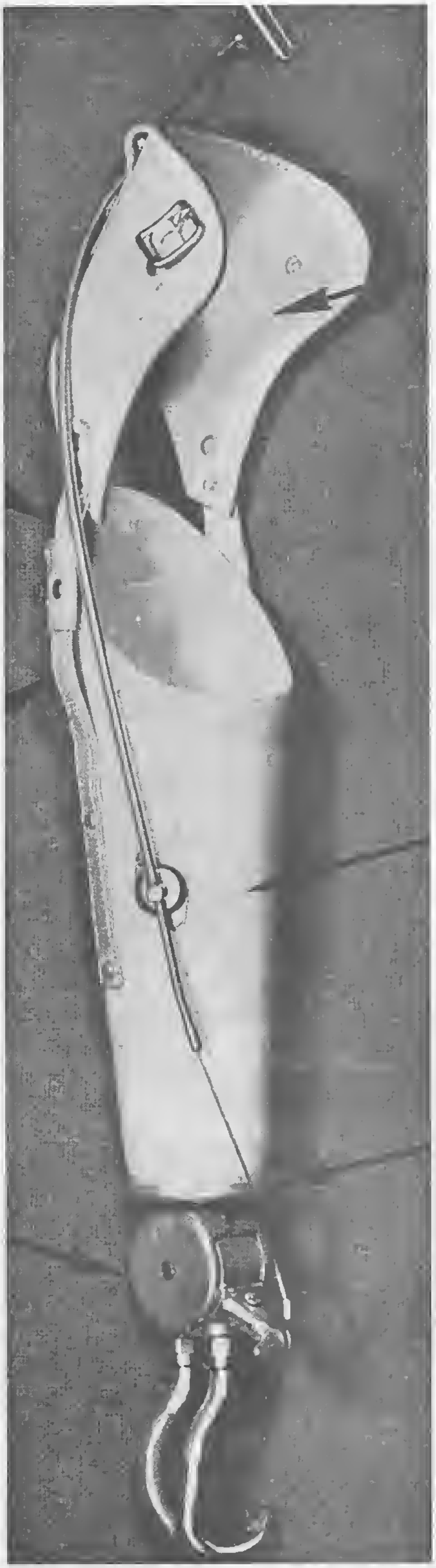
3



4

In picture 3, the cable tension has been released, and the driver is engaged with the keeper. The elbow is now unlocked. Finally, in picture 4, the cable is pulled again, and the cam pushes against the keeper causing it to disengage from the driver. Then the coil spring connected to the locking bar pushes the bar back into one of the slots in the gear strap, thus locking the elbow.

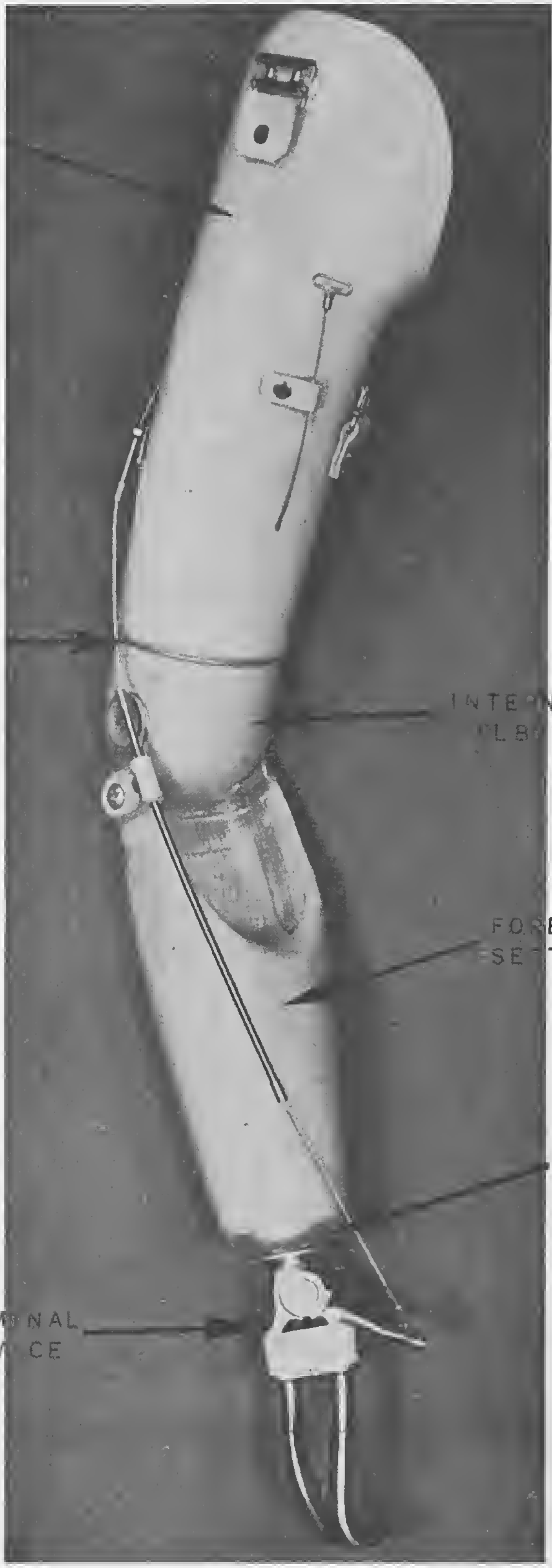
Exhibit 1. Examples of Manipulations with Artificial Arms



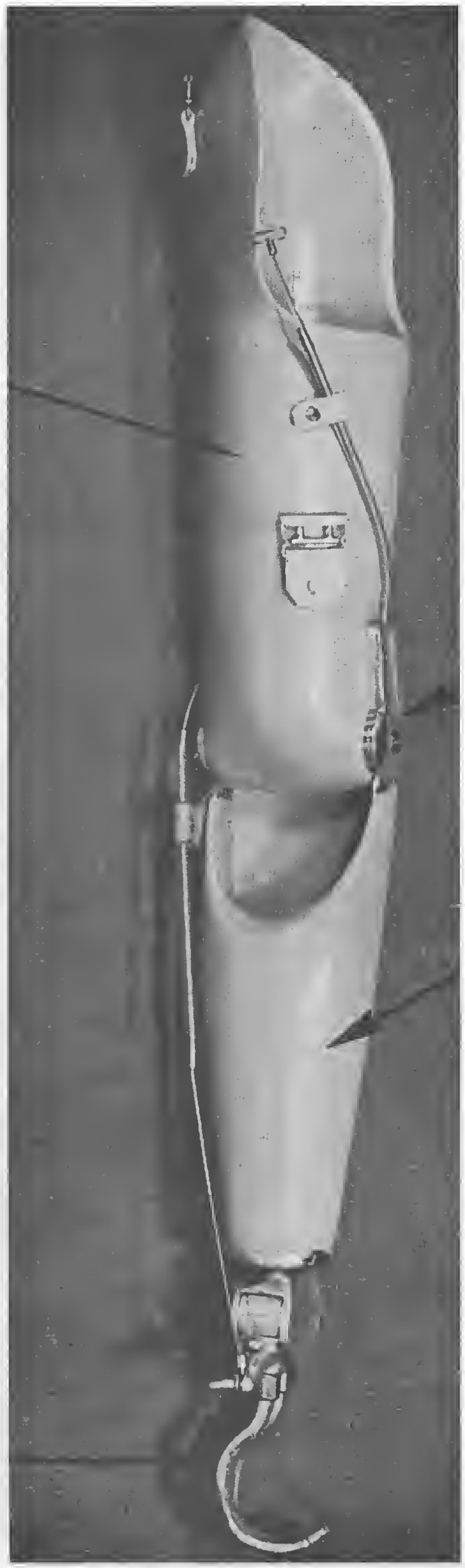
A: Prosthesis for a Lower Forearm Amputation (retail price about $300).

B: Prosthesis for an Upper Forearm Amputat: (retail price about $350)

Exhibit 2. Artificial Arms

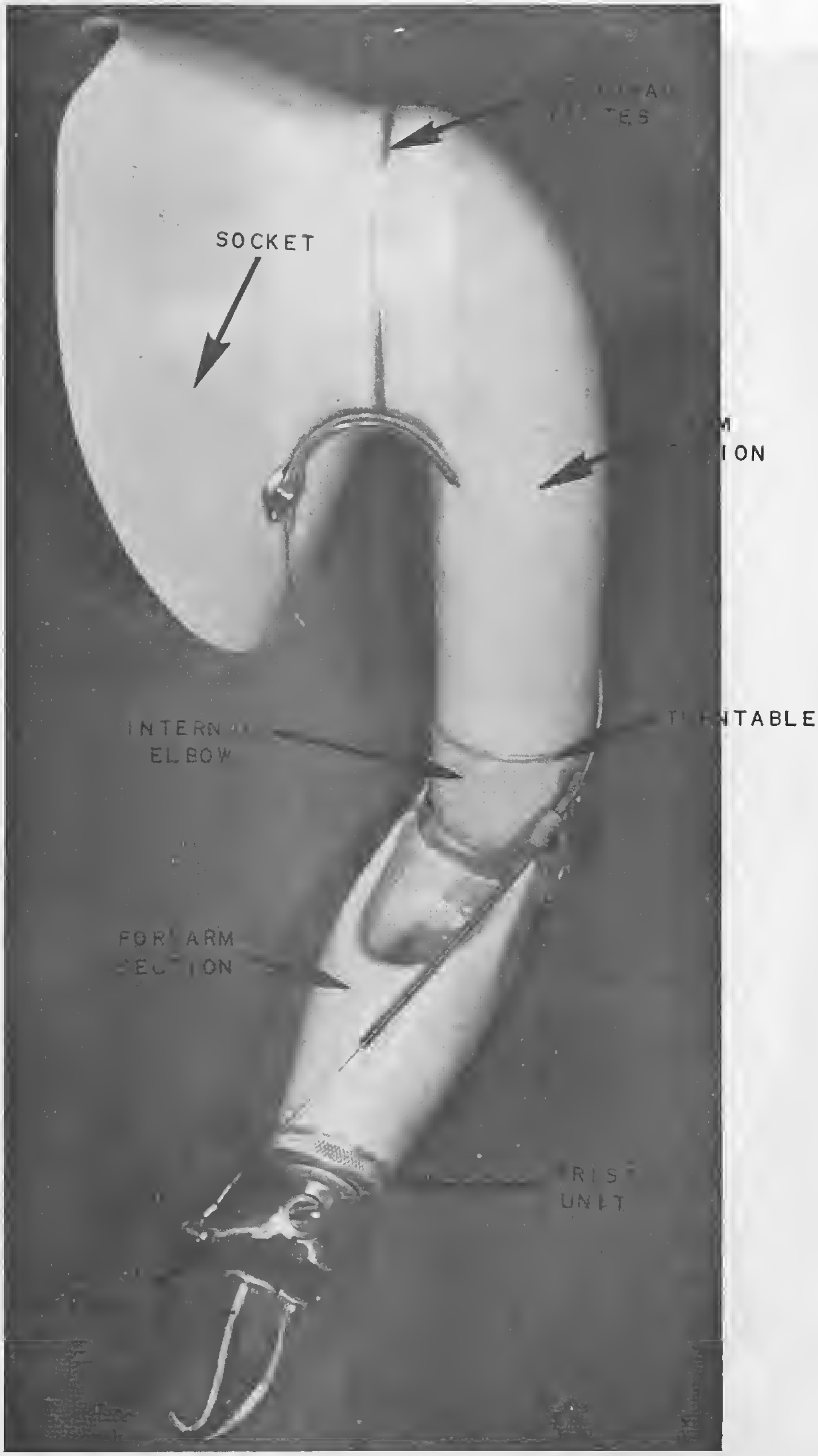


Prosthesis for an Upper Arm Amputation
retail price about $375)



D: Prosthesis for an Elbow Disarticulation
(retail price about $425)

Exhibit 2. Artificial Arms (cont.)



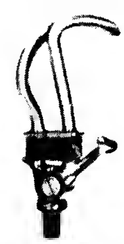
E: Prosthesis for a Shoulder Disarticulation
(retail price about $525)

Exhibit 2. Artificial Arms (cont.)

MODEL 12P
PLASTISOL COVERED
STAINLESS STEEL
2 OZ. 2¾" LONG
Right Model 12P illustrated.
Used with WE100 wrist with ¼" 28 thread insert.

MODEL 10AW
(WAFER)
PLASTISOL COVERED
ALUMINUM ALLOY
4 OZ. 3¼" LONG
Right Model 10AW illustrated.

MODEL 5X
NEOPRENE LINED
STAINLESS STEEL
7 OZ. 4 7/8" LONG
Left Model 5X illustrated.



MODEL 5
STAINLESS STEEL
7 OZ. 4 7/8" LONG
Left Model 5 illustrated.

* ALUMINUM ALLOY TERMINAL DEVICES FOR CHILDREN

The range of impairment is so great that the experience of a Prosthetist who knows the child is invaluable in making the right selection of the * Terminal Device.

The Model 12P fills the need for a very small device for the child as young as one year. The Model 12P can be operated by the mother. Some of the child's frustration is overcome as he learns he can hold small objects.

The Model 10AW is desirable where the child is learning to adjust. Safety Plate (Wafer) on the jaws and Plastisol overall dipping reduces chance of injury to amputee or other children. However, utility is reduced.

* STAINLESS STEEL TERMINAL DEVICES FOR ADULTS

The Model 5X stainless steel terminal device is the most desirable model where neoprene (rubber) lined jaws, and the durable stainless steel construction are desired. It has the best all purpose shape and is practical for use in many occupations. The lined jaws help greatly in opening doors and many other tasks and can be "retreaded" when rubber wears thin.

The Model 5 is the best known of all * terminal devices. From it the other * models have been developed. Desirable where replacement of rubber jaws would be a problem.

* HEAVY DUTY STAINLESS STEEL TERMINAL DEVICES FOR WORKING MEN

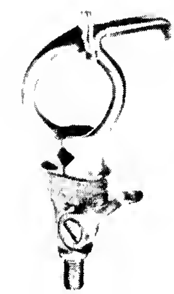
The Model 7 is the most popular device for farmers, truck drivers, and a large variety of workmen and has proven very useful in many occupations. Strong, heat treated stainless steel and ball bearing joint as in other * models.

This model can hold chisels, nails, butcher knives, and a variety of other tools.

The Model 7 L.O. has a larger opening for shovel handles than the Model 7. Some farmers prefer this model.

The Lock Hook is a very useful device for the skilled mechanic, carpenter and other similar trades. It is often used by farmers. Because of its close fitting mechanical parts, it should be kept clean. This terminal device, like all * models, is closed by rubber or metal springs, but it also has an automatic lock to keep it closed on an object. Useful for push-pull type of work.

MODEL 7
HEAVY DUTY
STAINLESS STEEL
8¾ OZ. 5¼" LONG
Right Model 7 illustrated.



MODEL 7 L.O.
(LARGE OPENING)
HEAVY DUTY
STAINLESS STEEL
9 OZ. 5¼" LONG
Left Model 7 L.O. illustrated.

MODEL 6
STAINLESS STEEL
HEAVY DUTY
(LOCK HOOK)
13 OZ. 5 7/8" LONG
Right Model 6 illustrated.

Exhibit 3. Terminal Devices
(average retail price $65)

(* company name deleted by request)

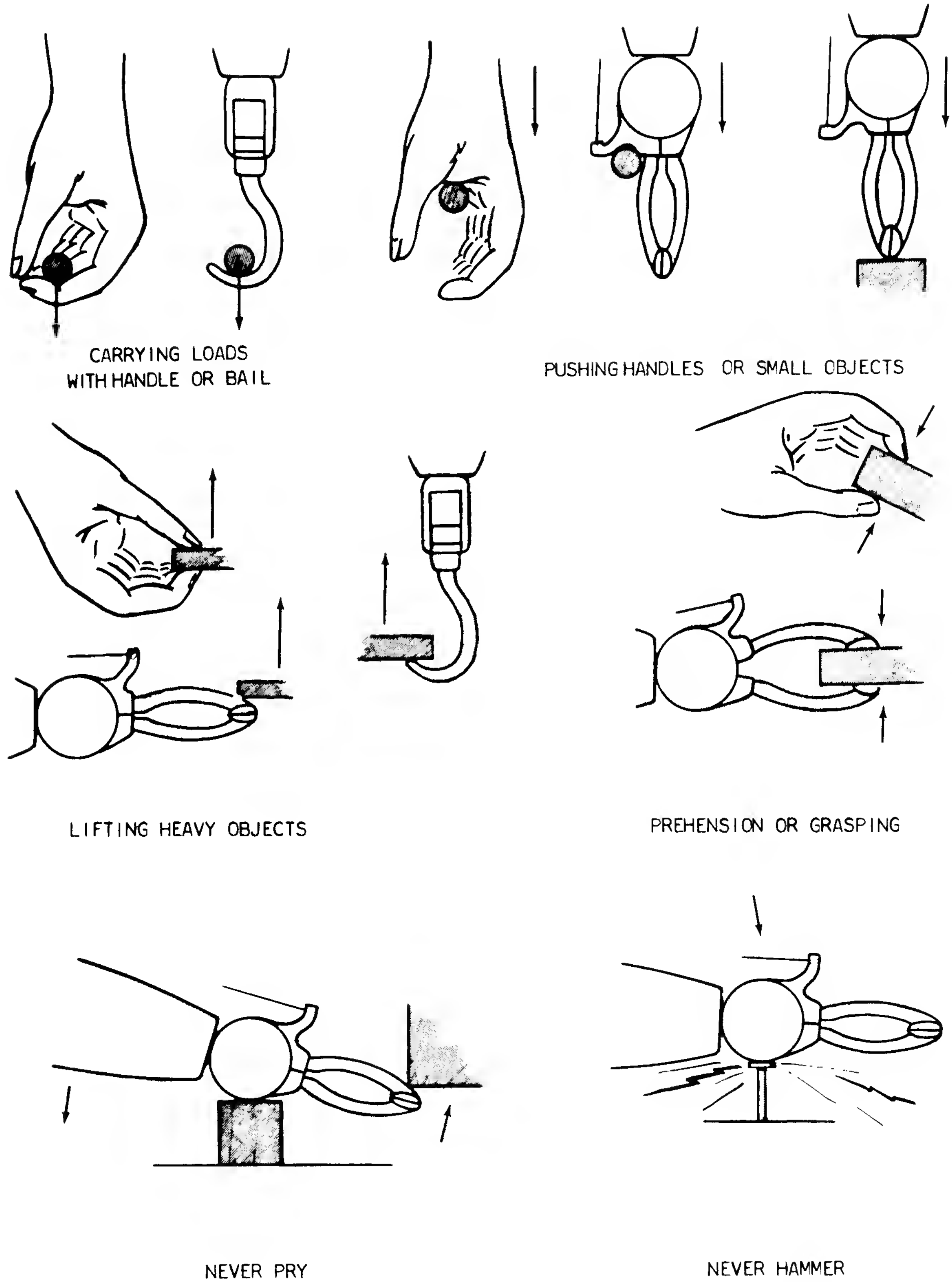


Exhibit 4. Use of the Split Hook

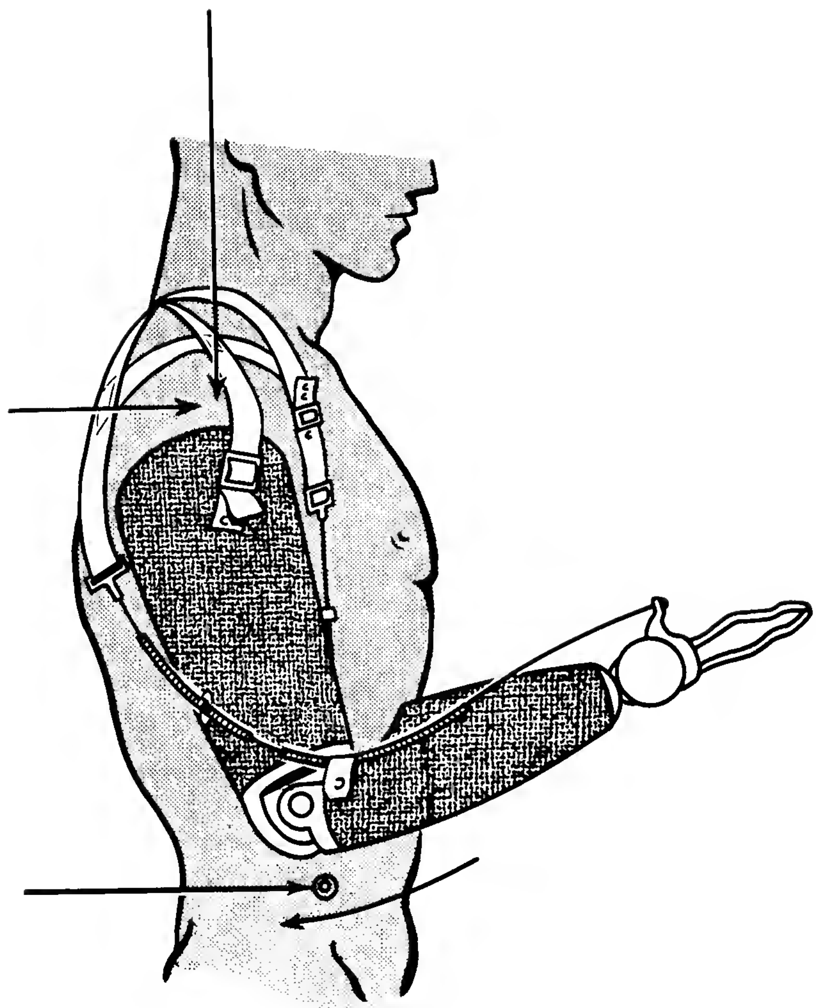
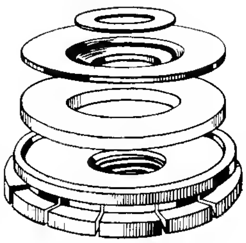


Exhibit 5. Typical Shoulder Harness



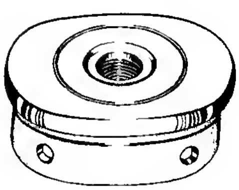
✲ WRIST DISARTICULATION UNIT

All stainless steel, friction type--used on very long below elbow stumps and wrist disarticulations. Made as thin as possible to save minimum overall length.

Until introduction of ✲ Oval Wrist listed below, this unit was used almost universally for this type amputation.

WA-600 Wrist Disarticulation Unit, adult size.
Solid stainless steel.
2″ overall outside diameter.

WA-600A Wrist Disarticulation Unit, child size.
Solid stainless steel.
$1\frac{3}{8}$″ overall outside diameter.

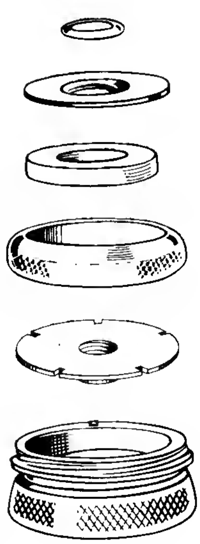


✲ OVAL FRICTION WRIST

Prosthetist and amputee alike will be pleased with the fine appearance and function of the completed prosthesis when using this new oval shaped wrist.

Developed for improved cosmetic appearance. Particularly suitable for wrist disarticulation or very long B.E. stumps having conical shapes. Also being used on other applications where oval shape is desirable.

OW-100 Adult size, aluminum with stainless threads.
OW-75 Child size

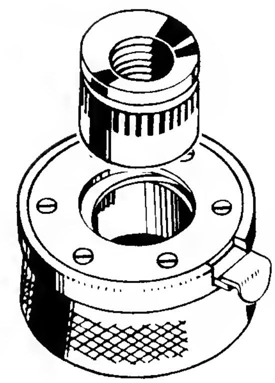


✲ ADJUSTABLE FRICTION WRIST

Cap screws on to hold stainless steel threaded plate against base section. This threaded plate can be positioned in the most desirable location for proper friction of terminal device—turn plate one notch for new adjustment. Threaded plate can be replaced if threads become damaged. Liked by Prosthetists because of large opening for breakout and wax drainage.

AF-700 Adjustable Friction Wrist
Aluminum with stainless threads.
2″ overall outside diameter.

FM WRIST DISCONNECT (Quick-change type)



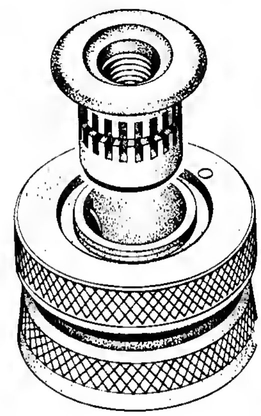
Developed under the program directed by the National Academy of Sciences Advisory Committee on Artificial Limbs, this wrist unit is particularly useful where both hand and hook are used alternately.

Light pressure on the control button maintains the terminal device in the arm, but allows it to be manually pronated or supinated. Pressure on the terminal device, towards arm, re-engages lock. Heavy pressure on the control button ejects the terminal device from arm.

Two inserts, FM-104, are furnished with each wrist. $\frac{1}{2}$-20 thread standard, $\frac{1}{2}$-27 on request.

FM-100 Wrist Disconnect
Complete with two FM-104 inserts.
2″ overall outside diameter.

✲ QUICK-CHANGE WRIST



A positive locking quick-change wrist disconnect. Enables the amputee to position or interchange from hand to hook in a matter of seconds.

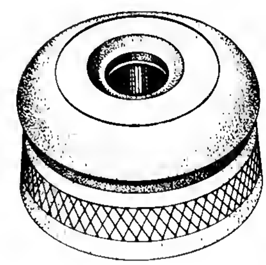
Wrist face is rotated in one direction to allow removal of terminal device. By rotating in opposite direction, terminal device is in "free wheeling" and can be manually rotated for correct position. With wrist face in central position, terminal device is in positive locked position and will not turn or pull out of wrist.

Some difficulty is experienced in rotating face when covered by cosmetic glove. Therefore, the FM-100 wrist shown on page 12 is preferred under these conditions.

WD-400 Standard weight
complete with two DA-101 inserts.
2″ overall outside diameter.

WD-400S Heavy duty model
complete with two DA-101S inserts.
2″ overall outside diameter.

✲ ECONOMY FRICTION WRIST



A simple screw-in friction wrist that is very popular with both Prosthetist and amputee. Available in a variety of sizes. Has stainless steel threaded bushing pressed into aluminum body

$\frac{1}{2}$-20 thread standard, $\frac{1}{2}$-27 thread on request.

Adult size available in solid stainless steel for heavy duty applications

STANDARD SIZE

WE-500 Aluminum with stainless threads.
2″ overall outside diameter.

WE-500S Heavy duty solid stainless steel.
2″ overall outside diameter.

MEDIUM-SMALL SIZE

WE-300 Aluminum with stainless threads.
2″ overall outside diameter.

CHILD SIZE

WE-200 Aluminum with stainless threads.
2″ overall outside diameter.

INFANT SIZE

WE-100 Aluminum body threaded for Infant Mit.
Removable $\frac{1}{2}$-20 thread stainless insert has $\frac{1}{4}$-28 threaded hole for ✲ #12P Infant Hook. Insert can be adjusted for proper hook position.

Exhibit 6. Wrist Connections
(average retail price $13)

UPPER EXTREMITY MEASUREMENT CHART

ECL-36

DATE ____________________

PATIENT'S NAME ____________________

STREET ADDRESS ____________________

CITY AND STATE ____________________

OCCUPATION ____________________ AMP. DATE __________

HEIGHT __________ WEIGHT __________

CHEST CIRCUMFERENCE __________ AGE __________

MALE ☐ FEMALE ☐

RIGHT ☐ LEFT ☐

CAUCASIAN ☐ NEGROID ☐ OTHER __________

AMPUTATION LEVEL ____________________

CATALOGUE # ____________________

TYPE WRIST __________ ELBOW __________ HINGE __________

OPEN SOCKET ☐ END BEARING ☐ SPLIT SOCKET ☐

STANDARD WEIGHT ☐ HEAVY DUTY ☐

MODEL HOOK USED ____________________

MODEL HAND USED ____________________

COMPANY NAME AND ADDRESS

____

____

____

PREVIOUS PROSTHESIS WORN? YES ☐ NO ☐

OLD PROSTHESIS MEASUREMENTS ____________________

UPPER, ACROMION TO ELBOW CENTER ____________________

LOWER, ELBOW CENTER TO END OF WRIST ____________________

IS THE PROSTHESIS TO BE COMPLETED READY FOR FITTING?

YES ☐ NO ☐

CAUSE OF AMPUTATION ____________________

____

____

____

____

HARNESS ☐ CUFF ☐ CABLES ☐

ROBIN AID HAND ☐ SIZE __________

BECKER HAND ☐ SIZE __________

LOCK GRIP ☐ PLYLITE ☐

HOSMER COSMETIC HAND ☐

SIZE ____________________

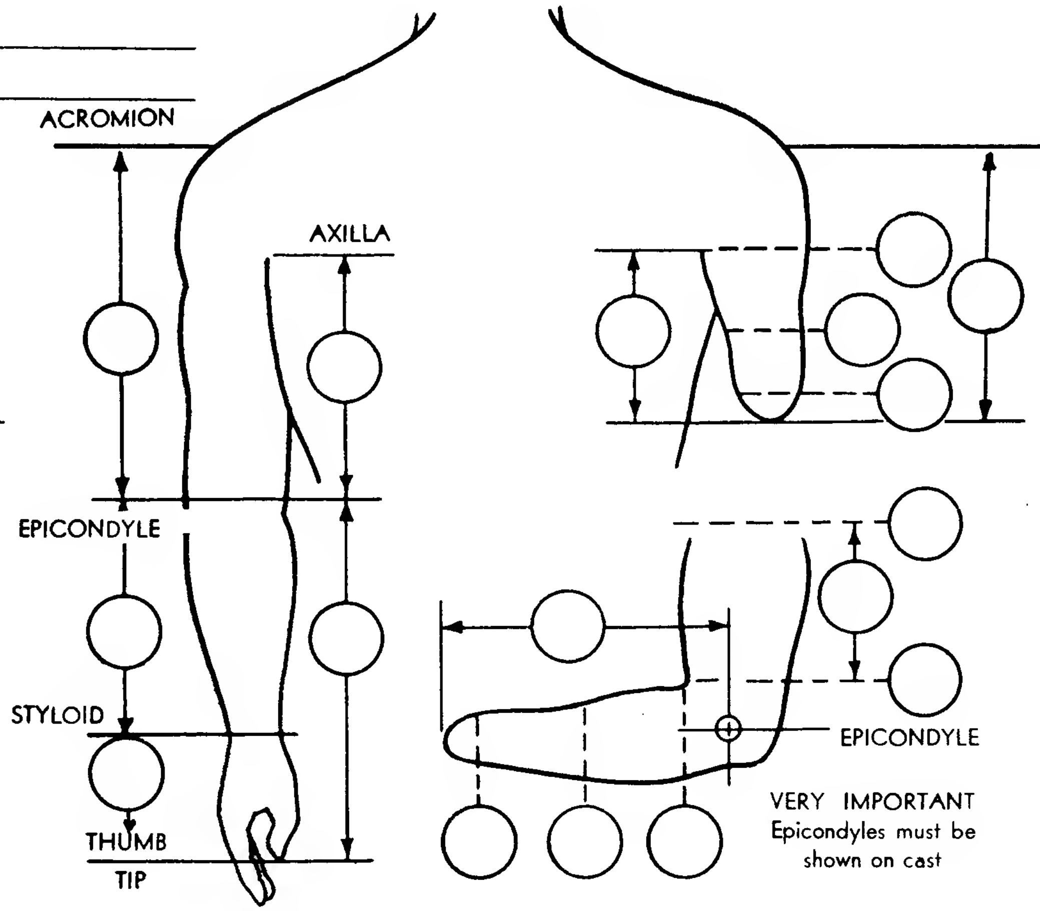
COSMETIC GLOVE ☐ SHADE # __________

OTHER ITEMS

____

____

____



REMARKS:

____

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____

NOTE: Please fill out complete with drawing of sound arm, etc.

Exhibit 7. Measurement Form